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Nutritional Determinants of Bone Health: A Survey of Australian Defence Force (ADF) Trainees

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ABSTRACT

Poor bone health is becoming increasingly common, and therefore is of concern for the ADF. Personnel at risk include those with habitually low dietary calcium intakes, or other dietary issues related to bone health. Dietary intakes of female cadets in training and male recruits upon entry to training were surveyed to determine whether individuals were at increased risk of poorer bone health. Approximately one third of respondents reported calcium intakes below the recommended levels, due to under-consumption of dairy foods. Female respondents were generally worse than their male counterparts. The majority of respondents reported at least two or more dietary risk factors that could negatively affect bone health.

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Executive Summary

A prerequisite to the maintenance of capability within the Australian Defence Force (ADF) is developing and maintaining physical fitness. Many injuries to ADF personnel recorded are preventable, and one area of preventive action yet to be tackled is the improvement of bone health. ADF personnel at risk of poor bone health include those with habitually low dietary calcium intakes, with increased calcium requirements due to strenuous physical activity, or with increased calcium losses via sweat. Those living in cold climates and submariners are also at risk due to poor vitamin D status. Dietary calcium is important for bone health, along with other dietary issues and many other factors contributing to bone health.

Female cadets from the Australian Defence Force Academy (ADFA) and Royal Military College - Duntroon (RMC) were surveyed during their academic/training year, and male recruits from Australian Recruit Training Centre - Kapooka (ARTC) were surveyed upon entry to recruit training. Calcium intake, along with intakes of energy, protein, sodium, phosphorus, magnesium, zinc and alcohol were determined for each respondent. Intakes were compared to Australian recommendations to determine whether individuals were at increased risk of poor bone health.

Approximately one third of respondents reported calcium intakes below the recommended levels, due to under-consumption of dairy foods. Female respondents were generally worse than their male counterparts. The majority of respondents reported at least two or more nutritional risk factors to bone health related to their intakes of protein, sodium, phosphorus, magnesium, zinc or alcohol.

The most important finding from the present study is that ADF trainees are at apparent risk of compromised bone health, due to a number of nutritional factors. It is recommended that the ADF provide nutrition education, promote a reduction excessive smoking and drinking, promote the consumption of dairy products, provide additional sources of calcium, consider supplementation in certain situations and monitor the dietary intakes of ADF personnel.

DSTO-Scottsdale has begun an ADF bone health survey (Task ARM 04/145) which aims to determine the prevalence of key risk factors, and to relate these risk factors to injuries. The results will assist in designing strategies for the prevention of bone-related injuries within the ADF.

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Julia Carins, BSc, began work at DSTO Scottsdale in 1996, and since that time has been involved with many research projects of varying nature. Whilst at DSTO Scottsdale she has undertaken work in Nutrition and Food Technology including work on iron supplementation for female cadets, salivary markers of immune function, nutritional analysis of combat ration pack items and determination of food acceptability.

Contents

1. INTRODUCTION 1

1.1 High Injury Rates within the ADF are a Concern 1

1.2 Bone Health as an Issue for the ADF 1

1.3 Military Research and Bone Health 2

1.4 Bone Health and Calcium 3

1.4.1 Calcium Intake 4

1.4.2 Calcium Absorption 5

1.5 Other Health Issues related to Calcium Intake 5

1.6 Recommended Dietary Intakes for Calcium 5

1.6.1 Current Australian Recommendations 5

1.6.2 Proposed Australian Revisions to Recommendations 6

1.6.3 Current US Recommendations - A New Approach 7

1.7 Other Nutrients and Food Components Affecting Bone Health 8

1.7.1 Energy Intake 8

1.7.2 Other Nutrients or Food Components 8

2. METHODS 11

2.1 Participants 11

2.2 Dietary Intake Measurement 11

2.3 Data Manipulation 11

2.4 Calcium Intake 11

2.5 Energy Expenditure 12

2.6 Other Nutrients and Total Risk Score 12

3. RESULTS AND DISCUSSION 13

3.1 Respondents 13

3.2 Calcium Intake 13

3.3 Energy Intake 15

3.4 Other Nutrients 17

3.4.1 Protein 17

3.4.2 Sodium 18

3.4.3 Phosphorus, Magnesium and Zinc 18

3.4.4 Alcohol 18

3.5 Total Risk from Nutrient Sources 18

4. CONCLUSIONS 20

5. RECOMMENDATIONS 21

6. REFERENCES 22

APPENDIX A: FFQ QUESTIONNAIRE 27

APPENDIX B: CALCIUM RICH FOODS 31

1. Introduction

1.1 High Injury Rates within the ADF are a Concern

A prerequisite to the maintenance of capability within the Australian Defence Force (ADF) is developing and maintaining physical fitness. A fit, trained and deployable force is especially important in the current climate, with additional pressures on human resources due to a global focus on 'anti-terrorism', continuing hostilities in the Middle East and instabilities in our region[1]. In addition, the ADF plays a major role in humanitarian activities and peacekeeping operations.

Injuries to ADF personnel result in manpower losses and increased medical and compensation costs. The ADF Health Status Report[2] revealed rates of injury within the ADF over 70% higher than the Australian all-industry average. Physical training and sport account for half of these injuries, the most common site for injury being lower limb (30% of injuries). Sprains and strains accounted for ~30% of injuries, fractures ~10%, and the most common mechanism for injury was falls, trips or slips (21%)[2].

Many of the injuries recorded were preventable, and preventive measures that have already been introduced include changed physical training regimes, management of sporting activities and gender-related changes to other physical activities (for example marching)[3]. Two other important areas of preventive action remain to be tackled, namely improved neuromuscular co-ordination (through specific training exercise and psychosocial approaches)[1] and improved bone health.

1.2 Bone Health as an Issue for the ADF

Bone health is becoming an increasingly important health issue. Osteoporosis affects about 30 per cent of postmenopausal women, with more than half of these suffering bone fractures[4]. It is also becoming more of a problem for men. The prevalence has been predicted to increase in the next generation and the effects of osteopenia (reduced bone mass) are already being seen more in younger people[5].

Poor bone health is shaping up to be a major health issue for the ADF. Personnel at risk include those with habitually low dietary calcium intakes, with increased calcium requirements due to involvement in strenuous physical activity, or with increased calcium losses via sweat due to deployment in hot climates. Those living in cold climates and submariners are also at risk due to poor vitamin D status.

This report addresses one of the aims of DSTO Task ARM 04/145 'Nutritional Strategies for Enhanced Readiness', sponsored by Director-General Defence Health Service. It addresses the following objectives and requirements of the ADF HHPR Master Plan:

1.2.2 Studies to prevent nutrition related illness, particular emphasis should be on the nutrition requirements of the training environment. Investigate factors that affect bone health.

It is clear from the literature that dietary calcium is important for bone health. There are, however, other dietary issues and many other factors contributing to bone health. These include genetics, hormones, physical activity, physical characteristics, alcohol and caffeine use, smoking and contraceptive use in women. Whilst this report may touch on some of these issues, it deals more specifically with the nutritional issues affecting bone health.

1.3 Military Research and Bone Health

The importance of dietary calcium in relation to stress fractures in military personnel is unclear. Studies have reported that calcium intake[6] or supplementation[7] was not associated with the risk of developing stress fractures in military recruits, but dietary calcium intake in injured and control groups was relatively high.

Lower bone density, however, was found to be a factor in predisposing male[8] and female[9] members of the US Marine Corps to the development of fractures. Also in the US, female recruits were found to have disproportionately higher numbers of stress fractures than male recruits undergoing similar training regimes[10, 11]. Lower bone mineral density has been found among athletes who lose calcium through profuse sweating without a compensatory increased intake of dietary calcium[12]. This could be an important consideration when considering the calcium requirements and bone health of ADF personnel operating in tropical environments.

Currently, a stress fracture research program is being conducted by the United States Department of Defense, and the U.S. Army Research Institute of Environmental Medicine is studying the influence of physical training programs on parameters of bone quality (primarily geometry and density). Recently Australia (DSTO-Scottsdale) has agreed to collaborate with this research through the TTCP program.

The US Defense Women's Health Initiative assessed risk factors for bone health in 4,139 female Army recruits, and the results (pending publication) were that the group of women with the lowest heel bone density quartile, who smoked and did not exercise, were at highest risk for stress fracture. The relative risk (RR) of stress fracture in this group was 14.4 times higher than other women in the study. Over 16% of the fractures occurred in this high risk subgroup (personal communication MAJ R Evans, USARIEM).

The Creighton University Osteoporosis Centre has begun a study which aims to determine if calcium and vitamin D intervention can reduce stress fracture incidence by at least 50% in female Naval recruits during basic training and to examine the

potential mechanisms for increasing bone adaptation to intense mechanical loading[13]. Over three years they aim to enrol 5,200 participants and compare the stress fracture incidence between placebo-treated and calcium/vitamin D treated women. Preliminary results should be available by the end of 2005.

DSTO-Scottsdale has begun an ADF bone health survey (under Task ARM 04/145) which aims to determine the prevalence of key risk factors, including diet, exercise, bone turn-over, bone mineral density and anthropometry, and to relate these risk factors to injuries. These data will be used as the basis for the design of strategies for the prevention of bone-related injuries within the ADF.

1.4 Bone Health and Calcium

Calcium is an essential nutrient and is the major cation of bone. As bone is a living tissue, it is continually being broken down and rebuilt. To enable this process, bone has a requirement for not only calcium, but also for an energy supply, and other nutrients including phosphorus, protein, ascorbic acid, copper, fluorine, iron, magnesium, manganese, vitamin D, vitamin K and zinc[14, 15]. Adequate amounts of these nutrients are essential for bone health.

The skeleton serves as the primary reserve for calcium, and is indirectly affected by dietary calcium intake and the amount of calcium lost from the body as either urine or sweat. Estimates of calcium requirements have only recently included amounts needed to replace calcium losses through sweat. This has lead to an increase in calcium intake recommendations in recent revisions of the FAO/WHO[16] and US/Canadian recommendations[17] and the draft revisions to the Australian/New Zealand recommendations[18].

Calcium also plays an essential role in the physiology of the nerves, muscles, and cell membranes. The calcium levels in the blood and tissues are carefully controlled by the interplay of a number of hormones. This means that when inadequate calcium is consumed, or calcium losses exceed intake, calcium is retrieved from the bone to balance the soft tissue levels.

When the body is in negative calcium balance, due to factors such as inadequate calcium intake, poor absorption, or high losses in sweat, bone health is compromised. Negative calcium balance leads to poor mineralisation of bone in the young, and resorption of calcium from the bone in adults, with a resulting reduction in bone strength. Inadequate amounts of the other bone related nutrients also contribute to poor bone strength. Reduced bone strength in adults increases the risk of bone related injuries, such as fractures in early adulthood, disorders such as osteoporosis in later life.

1.4.1 Calcium Intake

A recent review of the literature on the relationship between calcium intake and bone health[14] established that higher calcium intakes produced greater bone gain in children, and better calcium retention, reduced bone remodelling, reduced or halted age-related bone loss in adults[14].

Adequate calcium is required in childhood and adolescence to ensure proper development of the skeleton. Beyond this, maintenance of the bone mass during adulthood, and prevention of bone loss in later life is affected by calcium intake.

Inadequate calcium consumption contributes to several disorders, osteoporosis being the most commonly studied disorder. An effective deterrent against osteoporosis related fractures appears to be the achievement of maximal skeletal mass or peak bone mass by early adulthood[19], and it appears that a lifetime pattern of adequate calcium intake seems to produce the most benefit.

Bone health in adolescents and younger adults, and the consequences of poor bone health during younger adulthood, is an evolving area of research. Lower bone density has been associated with increased risk of forearm fracture in boys[20]. Also, children who avoided drinking cow's milk not only had low dietary calcium intakes and low bone mineral density (BMD), but were also more prone to fracture[21] than those who drank cow's milk.

Bone health in adults also appears to be affected by calcium intakes. Fracture rates were higher in a district in Yugoslavia where calcium consumption was low compared to a district with similar living conditions but where calcium consumption was high[22]. Studies have also found positive associations between calcium intake and bone health markers in young women[19, 23-27]. Milk drinking in men and adolescent boys has also been shown to have positive association with bone health markers[28, 29]. Adequate lifetime calcium consumption (defined as 1,200mg/day in adolescence and 800mg/day in premenopausal adulthood) was positively associated with bone health markers in women [19].

It is difficult to design studies to determine the factors affecting bone health in athletes, due to the lack of ability to control the training regimes and conditions for a group of athletes for the same period. Some studies have found that lower bone density is associated with oestrogen deprivation and calcium deficiency in female athletes[30]. Female athletes with stress fractures had lower bone density, higher menstrual irregularities and lower intakes of dietary calcium than controls[31]. In the same study, there was also a significant correlation between calcium intake and bone density. Higher numbers of stress fractures in female athletes compared to male athletes is thought to be linked to differences in diet, menstrual history and bone density, rather than gender itself[32].

1.4.2 Calcium Absorption

The effect of calcium intake on bones is not a simple linear relationship whereby the higher the intake, the greater the benefit. This is partly because the efficiency of calcium absorption into the body varies depending on a number of variables, including nutritional and physiological factors.

Efficiency of absorption is increased during periods of physiological requirement. For example, children — who have a greater requirement due to skeletal growth — absorb up to 75% of ingested calcium, whereas young adults may absorb only 20-40%[33]. Absorption is even less in the aged[34]. A higher percentage is also absorbed at lower intake levels[33].

Calcium requirements also exhibit a 'threshold' behaviour[35]. Benefits to bone health are seen only when calcium intake is increased from a deficiency level to the threshold, above which no further improvement is seen[15].

Although calcium intake is used to indicate whether or not physiological requirement is being met, this may not be a valid indicator, because the efficiency of absorption is usually unknown.

1.5 Other Health Issues related to Calcium Intake

Adequate calcium intake is most often associated with the risk of bone disorders, but evidence also suggests that protection against hypertension, colorectal cancer, kidney stones and lead poisoning could be obtained by maintaining adequate calcium intake[36].

1.6 Recommended Dietary Intakes for Calcium

There are no biochemical assays that reflect calcium nutritional status. Indirect indicators of calcium adequacy, related to the skeletal calcium content, are used in most studies of calcium nutriture. However, observational studies cannot separate complex interactions between genetic, dietary, level of activity and other environmental factors; and cannot be extrapolated to determine lifetime consumption levels. This, and the long latency period before bone disorders such as osteoporosis appear make it difficult to determine a requirement for calcium[17].

1.6.1 Current Australian Recommendations

Earlier recommendations for a recommended dietary intake (RDI) for calcium were established after consideration of the views of the FAO-WHO Expert Group and the US National Research Council recommendations. In 1985 the calcium RDI was revised based on new studies of calcium requirements. Balance studies had shown that the calcium reserve in the skeleton is so great that negative calcium balance may have to

continue for many years before bone failure occurs[37]. The recommendation incorporates a margin of safety, but the value is calculated to provide enough absorbed calcium to meet obligatory losses in 90 per cent of the population[37]. The current Australian RDI for calcium for adults (including 16-18 year olds) are shown in Table 1.

Table 1. Current Australian RDI for Calcium[37]

Age Bracket (yrs)	Male RDI (mg/day)	Female RDI (mg/day)
16-18	1000	800
19-64	800	-
64+	800	-
19-54	-	800
54+	-	1,000

To be able to meet the RDI, the National Health and Medical Research Council (NHMRC) gives advice on food groups and lifestyle patterns that will provide nutrients in adequate amounts. Calcium is found predominately in dairy foods, but smaller amounts can be found in bony fish, legumes, certain nuts, fortified soy beverages and breakfast cereals[18]. To obtain adequate calcium, the NHMRC recommends three serves a day of dairy foods[38]. The NHMRC also gives recommendations on the numbers of daily serves of cereals, fruits, vegetables, meat equivalents and extra foods.

1.6.2 Proposed Australian Revisions to Recommendations

Australian and New Zealand recommendations for calcium requirements are currently being reviewed. Draft recommendations have followed the approach used by the US (see below) of setting a recommended dietary intake based on the Estimated Average Requirement (EAR). The proposed recommendations for adults (including 14-18 year olds) are shown in Table 2.

Table 2. Proposed Australian/New Zealand Recommendations for Calcium Intake[18]

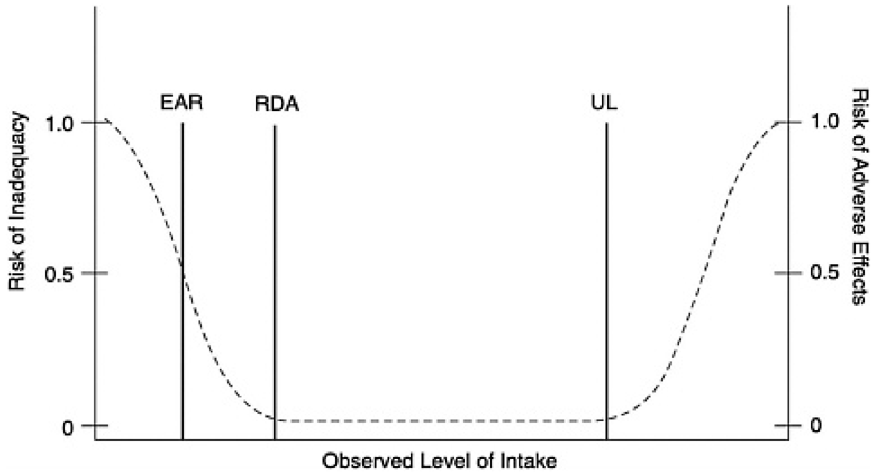
Age Bracket (yrs)	Male RDI (mg/day)	Female RDI (mg/day)
14-18	1,300	1,300
19-50	1,000	1,000
51-70	1,000	1,300
70+	1,300	1,300

For the purposes of this report it is worth noting that the proposed recommendations are substantially higher than the current Australian RDI, therefore estimates of dietary insufficiency made in the later sections of this report would be even greater if, or when the new recommendations are adopted.

1.6.3 Current US Recommendations - A New Approach

In 1999, the United States adopted a new approach for determining the required amounts of each of the nutrients. The US Recommended Dietary Allowances (RDAs) were replaced by Dietary Reference Intakes (DRIs). DRIs encompass the Estimated Average Requirement (EAR) the Recommended Dietary Allowance (RDA), the Adequate Intake (AI) and the Tolerable Upper Intake Level (UL)[17]. Figure 1 shows the links between the EAR the RDA and the UL.

Figure 1. Graphic representation of the EAR, RDA and UL.



*courtesy of Standing Committee on the Scientific Evaluation of Dietary Reference Intakes[17]

The EAR is the daily intake value that is estimated to meet the requirement of 50% of individuals in a specified group. The other 50% would not have their nutritional needs met at this level of intake. The RDA is the average daily dietary intake level needed to meet the nutrient requirements of nearly all (97 – 98%) healthy individuals in a specific group, and is set at two standard deviations (SD) above the EAR. The RDA is intended primarily for use as a goal for daily intake by individuals. The UL is the highest level of daily nutrient intake that is likely to pose no risks of adverse health effects in almost all individuals in the specified group[17].

An AI is set when data are considered to be insufficient or inadequate to establish an EAR on which an RDA would be based, and indicates that more research is needed. The AI is expected to meet or exceed the amount needed by essentially all members of a specific healthy population.

Instead of EARs, AIs were set for calcium because of (1) uncertainties in the methodology and nutritional significance of values obtained from balance studies; (2) a lack of concordance between observational and experimental data; and (3) the lack of longitudinal data associating calcium intakes, long-term bone loss and fractures. The recommended AI represents an approximation of the calcium intake that, in the

judgment of the DRI Committee, would appear to be sufficient to maintain calcium nutriture in most people while recognising that lower intakes may be adequate for some[17]. The current AI's for calcium are shown in Table 3.

Table 3. United States AIs for Calcium.

Age Bracket (yrs)	Male/Female AI (mg/day)
9-18	1,300
19-50	1,000
51-70	1,200
70+	1,200

1.7 Other Nutrients and Food Components Affecting Bone Health

1.7.1 Energy Intake

Total energy intake has also been found to be an important dietary factor with respect to bone mineral content (BMC) and bone mineral density (BMD)[26]. Lower energy intakes could indicate suboptimal nutrition, and therefore inadequate intakes of all of the nutrients important for bone health. In populations, lower energy intakes could indicate lower physical activity[39], and physical activity is a known promoter of bone health.

1.7.2 Other Nutrients or Food Components

There are a number of nutritional issues other than calcium intake that impact on bone health. Some of these nutrients or food components enhance or impede calcium absorption, or increase calcium losses from the body. Others affect bone health by mechanisms not closely linked to calcium intake.

One nutrient of great importance for bone health is vitamin D, a promoter of calcium absorption by enhancing absorption during times of need or reduced calcium intake. Poor vitamin D nutrition might be an important bone health factor among certain groups of ADF personnel, including those personnel who live in the southern states of Australia and submariners. Total sunlight deprivation for 68 days was reported to result in a large decrease in serum vitamin D among submariners[40]. Submariners and other ADF shift-workers may be at further risk of poor bone health due to altered circadian rhythm and resultant 'glucocorticoid-induced osteoporosis'[41]. Also of interest is the role of vitamin D in the promotion of neuro-muscular coordination. Poor vitamin D status is associated with impaired balance and muscular strength[41]. This is important when considering the role of poor neuro-muscular coordination in the high incidence of falls, trips or slips among ADF personnel[1]. Vitamin D can be obtained through the diet, or via skin synthesis when exposed to sunlight.

Adequate protein is essential for bone health as well as for many other aspects of metabolism. High protein intakes have been shown to increase urinary calcium

excretion[38], but there is controversy surrounding the notion that high protein diets can be detrimental to bone health. It is likely that a diet containing a moderate level of protein (1-1.5 g per kilogram body weight) is optimal[15].

Sodium intake has been linked to urinary calcium excretion, and considering the societal trend of low calcium and high sodium intakes[15] there is a potential for high sodium intake to adversely affect bone health. However the evidence is not conclusive that high sodium intakes necessarily adversely affect bone health[42].

Phosphorus is an essential building block of bone, and is therefore required in adequate quantities to ensure healthy bones. However there is concern that too much phosphorus could be harmful to bone. Parathyroid hormone (PTH) secretion increases bone resorption of calcium, and elevated serum phosphorus concentration affects parathyroid hormone (PTH) secretion. The replacement of milk drinks with carbonated beverages may also contribute, due to lowered calcium intake rather than elevated phosphorus intake[15].

Severe magnesium deficiency also affects PTH secretion[15], disrupting the calcium homeostatic mechanism[43].

Zinc is also necessary for bone formation. As a cofactor for several enzymes, zinc is required for bone mineralisation and development of the bone structure[44]. Zinc deficiency impairs protein metabolism, and reduces the concentration of zinc in the bone[15].

Vitamin K protects against age related bone loss via vitamin K dependent γ-carboxylation of certain bone proteins, including osteocalcin[45] — the major non-collagenous protein incorporated in bone matrix during bone formation. The ratio of undercarboxylated osteocalcin (a protein with low biological activity) to total osteocalcin is thought to be the most sensitive marker of vitamin K status[46] and both low dietary vitamin K[45] and increases in undercarboxylated osteocalcin[47] have been linked to low BMD in women. It has also been implied that vitamin K reduces urinary calcium excretion, and enhances vitamin D mineralisation and calcium deposition[48].

Bone health is also linked to good copper nutriture. Those with both copper deficiency and osteoporosis have decreased osteoblast activity[49]. Supplementation of calcium with trace elements (including copper) produced beneficial effects on bone density when compared to those supplemented with calcium alone[50].

High levels of caffeine in the diet are also detrimental to bone health. Caffeine reduces calcium absorption and increases urinary losses. A study found that as coffee intake increased, milk consumption decreased[51], compounding the problem.

Consumption of large amounts of alcohol is also detrimental to bone health. Alcoholism is a risk for bone health due to poor nutrition, malabsorption of nutrients, the potential for liver disease, direct toxicity to osteoblasts and increased risk of falls[15]. The notion of potential health benefits from moderate alcohol intake is quite popular, and it appears that moderate alcohol intake could be beneficial to bone health[52]. The recommendations for each of the other nutrients examined in this report are shown in Table 4.

Table 4. Australian Recommendations for other Relevant Nutrients/Components[37, 38]

Nutrient	RDI
Protein	0.75 g /kg bodyweight
Sodium	920 – 2,300 mg
Phosphorus	1,000 mg * upper limit of 3 times Ca intake
Magnesium	320 mg (men) 270 mg (women)
Zinc	12 mg

Food Component	Recommendation
Alcohol	Upper limits: 20 g/day (men) 10 g/day (women)

The survey we used did not estimate vitamin D, vitamin K, copper or caffeine intake, so this report does not analyse the intake of these nutrients/components by the respondents.

2. Methods

2.1 Participants

Female officer cadets from the Australian Defence Force Academy (ADFA) and female staff cadets from the Royal Military College - Duntroon (RMC) were surveyed during their academic/training year. Male recruits from the Army Recruit Training Centre - Kapooka (ARTC) were surveyed upon entry to recruit training.

2.2 Dietary Intake Measurement

A food frequency questionnaire (FFQ) developed by the Anti-Cancer Council of Victoria was used to assess the usual dietary intake of each participant. This is a 96item questionnaire that determines usual eating patterns. It has been validated and performs well compared to other methods used in this area[53]. A copy of the questionnaire can be found at Appendix A.

No measurement of dietary intake is error free, with tendencies to underestimate nutrient intakes. The FFQ used in this study was designed to assess iron intake, and was validated against seven day weighed food records. While variation between the two methods for estimated iron intake was only 1.9%, the estimated intakes for the nutrients of interest to us in this study – calcium (variation of 3.4%), energy, protein, sodium, magnesium, phosphorus and zinc — varied by less than 10% between the two methods.

Scanning and analysis of FFQ forms was conducted by the Anti-Cancer Council of Victoria with data in the form of nutrient intakes and food serves returned to DSTO-Scottsdale.

2.3 Data Manipulation

A ratio of energy intake (EI) to Basal Metabolic Rate (BMR) of 0.9 represents the lower 80% confidence limit for a plausible level of energy intake in relation to BMR when derived from a seven day food record for an individual[54, 55]. Respondents reporting an EI less that 0.9 of calculated BMR and respondents who had completed the FFQ incorrectly were excluded from dietary data analyses.

2.4 Calcium Intake

Each respondent's intake of calcium was compared to the Australian recommended daily intakes (RDI) to determine whether consumption was adequate.

2.5 Energy Expenditure

Energy expenditure for the female cadets training at ADFA and RMC was estimated using the factorial method of assigning values for the energy costs of activities in a usual day[56, 57]. A usual day was based on 1 hour of military drills, 7 hours of lectures, 2 hours of physical training (1 hour low level sport and 1 hour medium level sport), 8 hours of sleep/rest and personal activities/study/free time. From this calculation, an average physical activity level (PAL), the daily energy expenditure expressed as a multiple of basal metabolic rate (BMR) of 1.7 was assigned to the cadets. This level of activity is representative of a light level of energy expenditure.

An average PAL of 1.5 was assigned to the male recruits, recognising their pre-training activity levels.

The estimated BMR of each respondent was calculated using the method described by Schofield[55]. The estimated BMR of each respondent was then multiplied by the PAL to obtain an individual energy requirement in kilojoules. This was then compared to their reported energy intake to determine if they were meeting their energy requirement.

2.6 Other Nutrients and Total Risk Score

Intakes of protein, sodium, phosphorus, magnesium and zinc were compared to the Australian recommended daily intakes (RDI) to determine whether consumption was adequate. Alcohol intake was compared to the current Australian recommendations for maximum alcohol intake by men and women.

A risk score of one or zero was calculated for each nutrient listed above, and for alcohol. Each of the following resulted in a risk score of one for that nutrient: protein intake at twice the RDI, sodium above the upper limit of 2,300mg/day, phosphorus levels above the upper limit of three times the calcium intake, and magnesium and zinc below the RDI. Alcohol intake above the recommended upper limit also resulted in a score of one. A total for each respondent was determined by adding the risk score from each nutrient and alcohol, resulting in a possible total risk score between zero and six. This total risk score represents the degree of risk to bone health from the nutritional sources we measured.

3. Results and Discussion

3.1 Respondents

The dietary intakes of 57 female officer cadets from ADFA, 20 female staff cadets from RMC – Duntroon, 51 male and 7 female recruits from ARTC - Kapooka were assessed as part of two separate studies. After exclusions based on criteria aimed at maximising the validity of the data, 111 respondents remained — 67 female cadets (48 ADFA and 19 RMC) and 44 male recruits (ARTC). The mean age of respondents was 21 years (female mean 20 years, range 17 - 35; male mean 22 years, range 18 - 33).

The data set generated represented two different situations — the dietary intake of female cadets whilst undergoing training, and the dietary intake of male recruits immediately prior to commencing training. Distinctions have been made between the two throughout the remainder of this report.

3.2 Calcium Intake

Approximately one third of respondents had reported calcium intakes below the Australian RDI. The percentage of those who reported consuming inadequate amounts of calcium was higher amongst the female cadets than the male recruits. Table 5 presents the frequency and percentage of respondents who reported consuming inadequate amounts of calcium.

Table 5. Frequency and Percentage Reporting Consumption below the Calcium RDI

	Total Respondents	Female Cadets	Male Recruits
Frequency below RDI	36	28	8
Percentage below RDI	32%	42%	18%

Not only was the proportion of female cadets who reported consuming below the calcium RDI higher than that for male recruits, generally the consumption was lower. The median reported calcium consumption for female cadets was 105% of the RDI.

For the male recruits, the majority reported consuming over 125% of the RDI for calcium, the median reported calcium consumption being 130% of the RDI.

Figures 2 and 3 show the spread of reported calcium intakes.

Figure 2. Reported Calcium Intake Levels for Female Cadets

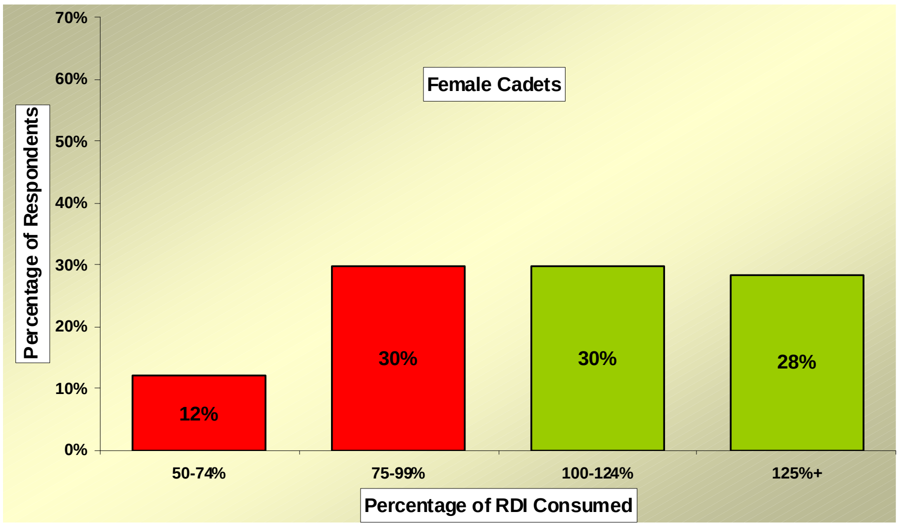
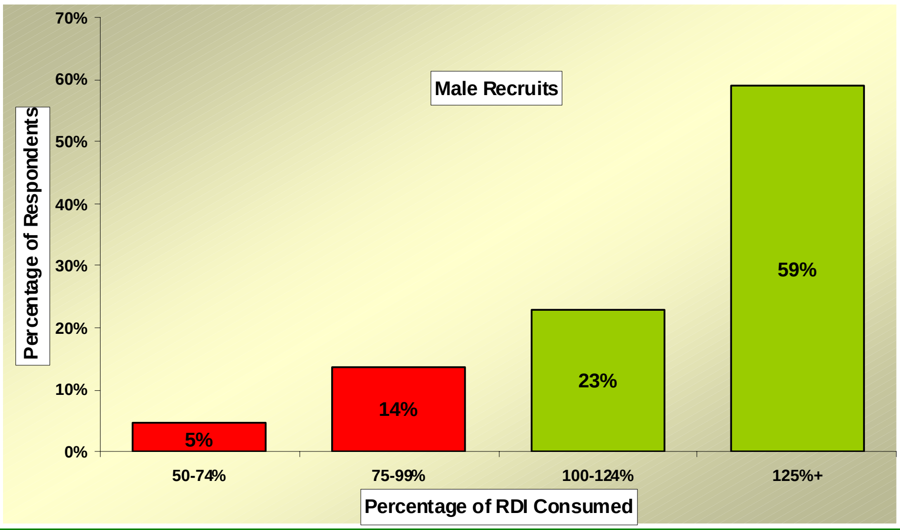


Figure 3. Reported Calcium Intake Levels for Male Recruits



One problem with asking participants to report food intake is the tendency of people to under-report intake[58-61]. However, the food frequency questionnaire used in this study had been validated against seven-day weighed food records, with calcium intakes estimated by the two methods varying by only 3.4%[53].

Of the respondents who reported consuming less than the calcium RDI, all consumed less than the recommended three serves per day of dairy foods. A further 58 respondents consumed less than the three serves per day of dairy foods, however they were still able to meet the RDI for calcium.

These results demonstrate that a substantial number of respondents were consuming inadequate amounts of calcium. Considering all the respondents in this survey had the

freedom to choose the types of food they consumed (either within the restriction of what is provided by the mess, or unrestricted by eating at home or out), the results suggest a certain percentage did not, by choice, consume enough high calcium foods. It may indeed be worse for those who do not use the mess and cook for themselves. Most ADF trainees do not have a lot of time to prepare meals, and have little knowledge of good nutritional principles, the result being a suboptimal diet.

These results are reasonably similar to those obtained in a previous study with ADFA female officer cadets, using three 24-hour dietary recalls in a four month period[62]. That study found 29% of female officer cadets reported calcium intakes below the RDI, less than the 42% reported in this paper for female officer cadets. Apart from the possibility that there is a 'real' difference—i.e. calcium intake was less for female officer and staff cadets in this study—there are also methodological differences between the two studies that may have contributed to the apparently higher rate of under consumption in this study.

Failure to meet the RDI for calcium does not necessarily constitute calcium 'deficiency'. The RDI is set at the estimated average requirement plus two standard deviations. Therefore, the apparently high level of failure to achieve the RDI can only be taken as an indication of potential, rather than actual, insufficiency of calcium intake.

It is reasonable to expect that this group is better educated and may be more aware of the principles of good nutrition than many other female ADF populations. Hence other ADF populations may be at even greater risk of insufficient calcium intake.

3.3 Energy Intake

From the results of the FFQ it appears that a large number of respondents reported food intakes apparently not meeting their estimated energy requirements. However, this most likely reflects on the nature of the FFQ method rather than actual dietary intakes, because there was no evidence of respondents being underweight. For example the average body weight of the female cadets was 65kg (range 51 – 83kg); and the average body weight of the male recruits was 78kg (range 60 – 98kg). Furthermore it was established that the female cadets general eating habits and weight remained stable over a 13 week period. As there was no indication that the officer cadets were in negative energy balance, the relatively high levels of apparent under consumption most likely indicate under-reporting.

Of the female cadets, 81% reported energy intakes below their estimated requirements, as did 45% of the male recruits. Some respondents (45% of female cadets and 16% of male recruits) reported not even consuming 75% of their estimated requirement.

Figures 4 and 5 show the spread of reported energy intake levels.

Figure 4. Reported Energy Intake Levels for Female Cadets

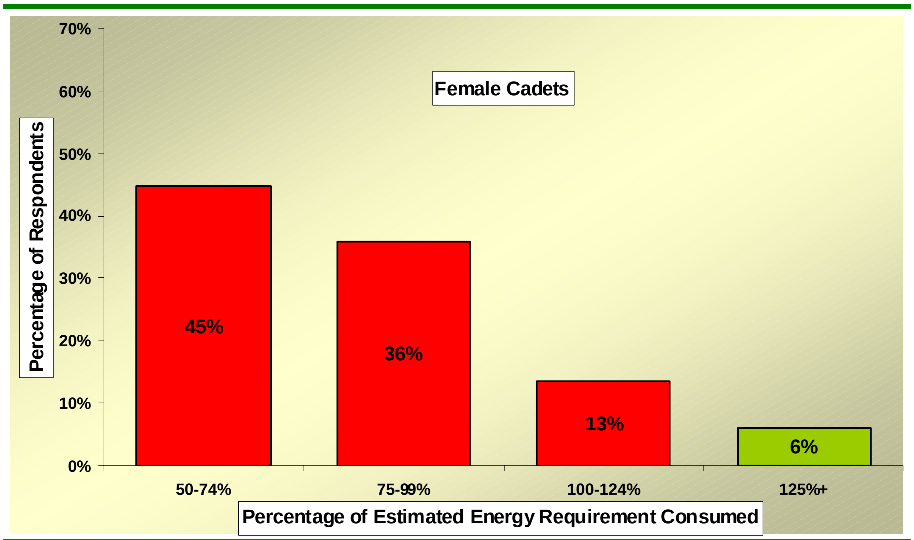
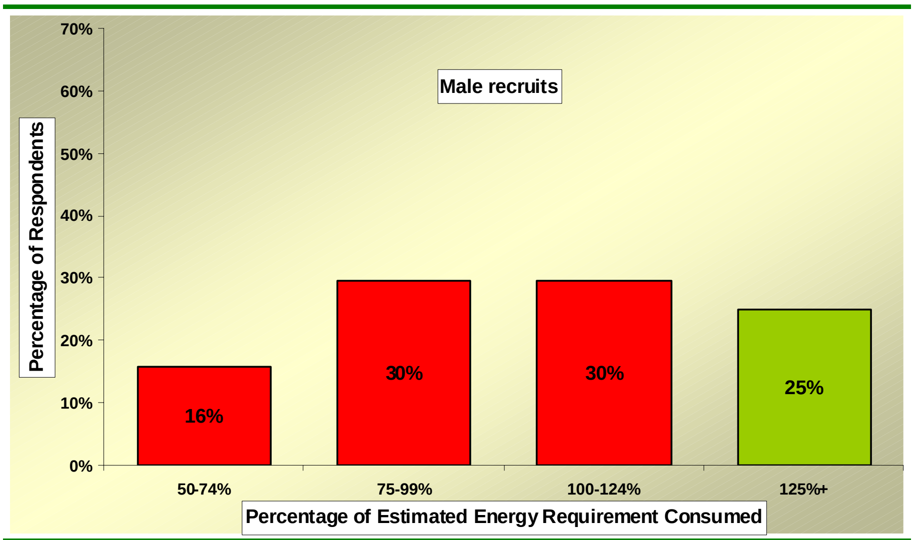


Figure 5. Reported Energy Intake Levels for Male Recruits



A number of respondents reported consumption of fewer than the recommended daily number of serves of cereals, and thereby may have been under consuming carbohydrates, the most valuable source of energy in the diet. A total of 28% of women reported consuming less than the recommended 4-9 daily serves of cereals. A higher level of men reported under consuming cereals, with 72% reporting less than the 6-12 recommended daily serves.

However, in light of the apparent under-reporting of total energy intake, it would be inappropriate to conclude that cereal consumption is particularly low. The relatively low estimated PAL of these cadets (1.7, corresponding to a light level of energy expenditure) also indicates that there is no need for large quantities of carbohydrate-

based ‘energy’ foods. Figures 6 and 7 show the number of serves of cereals reportedly consumed.

Figure 6. Cereal Servings Reportedly Consumed by Female Cadets

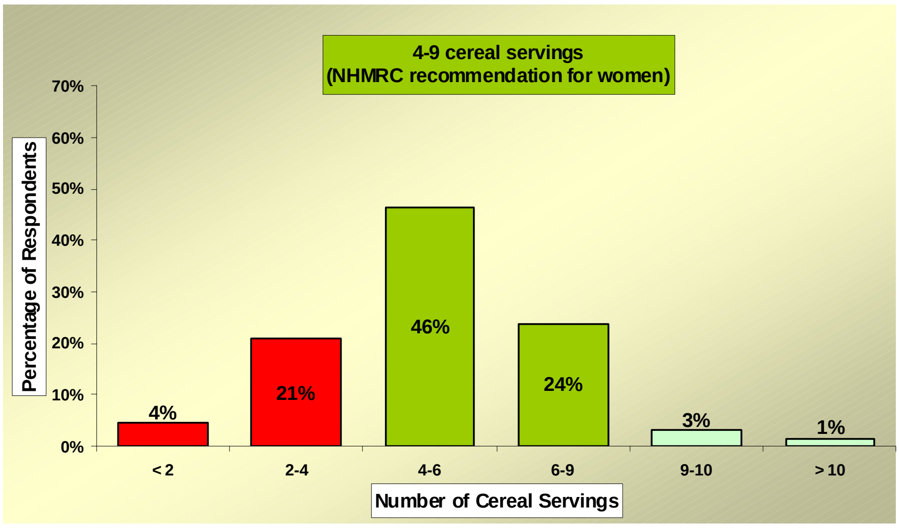
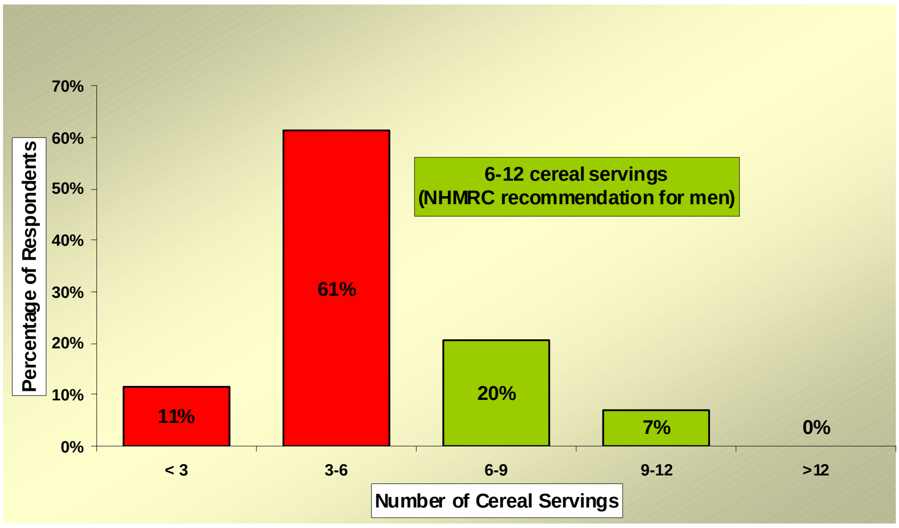


Figure 7. Cereal Servings Reportedly Consumed by Male Recruits



3.4 Other Nutrients

3.4.1 Protein

Most respondents (94% of female cadets and 100% of male recruits) reported consuming protein at or above the level of the RDI. The number of respondents consuming protein at twice the RDI or higher was substantial (30% of female cadets and 59% of male recruits). In view of the likely under-reporting of total food intake discussed above, protein intakes may have been even higher than reported for many

respondents. A high level of protein intake is associated with increased calcium excretion, so the intakes reported here could potentially have a detrimental effect on calcium balance.

3.4.2 Sodium

Reported levels of sodium in the diet of the respondents were generally above the Australian maximum recommended intake, with 18% of female cadets and 70% of male recruits reportedly consuming over 1.5 times the RDI upper limit of 2,300 mg per day of sodium. Only 28% of female cadets reported intakes within the recommended sodium intake range the remaining 72% of female cadets and all of the male recruits reported high sodium intakes. Whilst this is not unexpected, considering the societal trend of high sodium diets, it is possible that these individuals will have increased calcium losses, negatively affecting their calcium levels.

3.4.3 Phosphorus, Magnesium and Zinc

Most of the respondents (91% of female cadets and 100% of male recruits) reported phosphorus intakes above the RDI. The largest proportion of these (40% of female cadets and 77% of male recruits) reported intakes over 1.5 times the RDI. However, only one respondent reported a phosphorus intake over the upper limit of three times their calcium intake. Reported magnesium intake was lower than the RDI for 46% of the female cadets and 30% of the male cadets. Reported zinc intake was lower than the RDI for 60% of the female cadets and 14% of the male cadets. Each of these three variables (high phosphorus, low magnesium and low zinc) increase the risk to bone health for the individuals concerned.

3.4.4 Alcohol

Alcohol consumption by the respondents varied greatly, with 38% consuming more than the recommended upper limit of one standard drink per day for women (10 g alcohol) and two standard drinks per day (20 g alcohol) for men. The distribution of high consumers between the genders was reasonably even, with 43% of the female cadets and 30% of the male recruits consuming alcohol at higher than recommended levels.

3.5 Total Risk from Nutrient Sources

All respondents (bar one) had at least one risk factor, with the majority having two or more risk factors for impaired bone health. Figures 8 and 9 show the percentage of respondents for each total risk score.

Figure 8. Distribution of Female Cadets by Total Risk Score

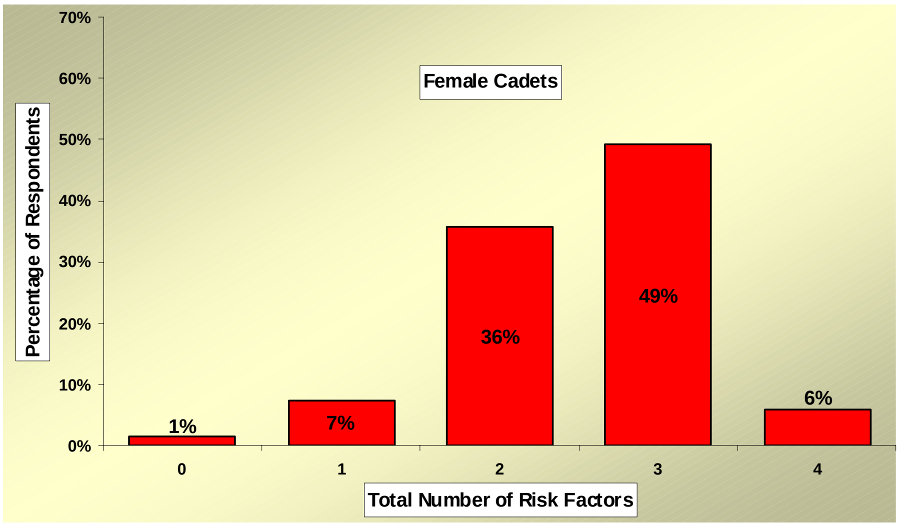
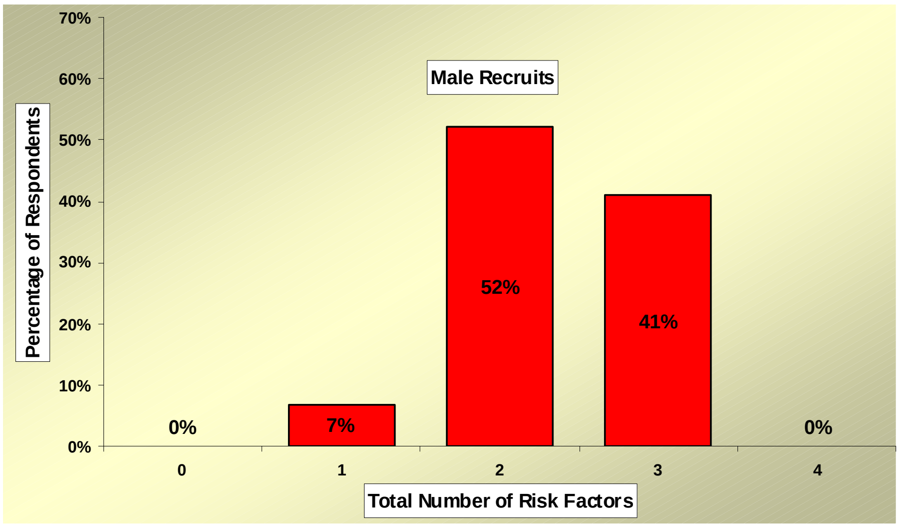


Figure 9. Distribution of Male Recruits by Total Risk Score



Of those whose reported intakes were below the calcium RDI, most (89% of those female cadets and all those male recruits) had a total risk score or two or more. It is possible that the low calcium intakes reported by these respondents may have been further exacerbated by the negative effects of these other nutritional risk factors.

Almost all of the respondents who reported consuming recommended levels of calcium had a total risk score or two or more (93% of those female cadets and 92% of those male recruits). It is possible that those respondents consuming close to the RDI may actually have a dietary calcium deficiency due to the action of the other risk factors.

4. Conclusions

The best protection against poor bone health is appropriate resistance exercise, a life-long calcium-rich diet and avoidance of smoking and excessive alcohol consumption. ADF personnel undergoing training, that involves high levels of physical activity, and may additionally be conducted in hot conditions, have an increased requirement for calcium. Submariners, personnel engaged in prolonged periods of 'shift' work, and personnel living for extended periods in cold climates may have additional bone health risk factors related to poor vitamin D status and altered diurnal rhythm.

The most important finding from the present study is that ADF trainees may be at apparent risk of compromised bone health, due to a number of nutritional factors. Approximately one third of male Army recruits and female ADF cadets reported under consumption of calcium, and 99% of trainees had at least one other nutritional risk factor that would contribute to lowered calcium retention, or poorer bone health via another means. Under consumption of dairy products was the main reason for poor dietary intake of calcium.

The other nutritional risk factors were high protein and sodium intakes, alcohol consumption above the recommended upper limit, low magnesium intake and low zinc intake.

5. Recommendations

1. **Provide nutrition education:** The need to consume adequate dietary calcium should be promoted as part of a nutrition education program. An holistic approach to nutrition education is needed. Such a program would not only include some formal lecture material for trainees and instructors, but also involve staff and management of the various food providers. In particular, trainees need specific instruction in making appropriate food choices to meet the nutritional demands of arduous activities. Education at the beginning of a trainee's military career will help promote good dietary habits over their time in the ADF.

2. **Reduce excessive smoking and drinking:** Health promotions aimed at reducing the prevalence of smoking and excessive alcohol consumption should also point out the negative impact on bone health and the resultant increased risk of injury.

3. **Promote the consumption of dairy products:** Reported under consumption of dairy products was the main reason for apparently poor dietary intake of calcium. Sufficient and good range dairy foods should be provided within the mess and should include low-fat varieties. Similarly, dairy products should be included in the 'hot boxed' meals provided to trainees outside the mess. Inclusion of low-fat milk drinks in vending machines and at commercial outlets on Defence sites should be encouraged. Trainees should be encouraged to eat at least 3 serves of low-fat dairy foods each day. To determine what constitutes an average serve of dairy food see Appendix B.

4. **Provide additional sources of calcium:** Although calcium is found predominantly in dairy foods, smaller amounts can be found in fish products where the whole bones are consumed, in legumes and certain nuts or in fortified soy beverages or breakfast cereals. It is recommended that tinned salmon be provided within the mess and other food outlets on Defence sites.

5. **Consider supplementation in certain situations:** Additional sources of calcium such as supplements should be considered for ADF personnel engaged in strenuous physical activity in hot climates, particularly where combat ration packs (CRP) are the major source of nutrition and where dairy products are not readily available. Bioavailability from non-food sources (e.g. supplements) depends on the dosage and whether they are taken with a meal. Efficiency of absorption of calcium from supplements is greatest at doses of ~500 mg. Calcium citrate, calcium carbonate and tricalcium phosphate are suitable supplements, which compare well with milk in terms of calcium bioavailability when consumed with a meal[18].

6. **Monitor the dietary intakes of ADF personnel:** There needs to be an ongoing program of monitoring the dietary intake of ADF personnel, with a particular focus on the nutrients most likely to have a negative affect on capability, such as the nutritional risk factors for bone health discussed in this report.

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Appendix A: FFQ Questionnaire

Dietary Questionnaire

Questions about what you usually eat and drink

Please fill in the date you completed this questionnaire:

DAY	MTH	YEAR
0	JAN	1996
1	FEB	1997
2	MAR	1998
3	APR	1999
4	MAY	2000
5	JUN	2001
6	JUL	2002
7	AUG	2003
8	SEP	2004
9	OCT	2005
	NOV	2006
	DEC	2007

INSTRUCTIONS:

This questionnaire is about your **usual** eating habits **over the past 12 months.** Where possible give only **one answer per question** for the type of food you eat **most often.** (If you can't decide which type you have most often, answer for the types you usually eat.)

- Use a soft pencil only, preferably 2B.
- Do not use **any** biro or felt tip pen.
- Erase mistakes fully.
- Make no stray marks.

Please MARK LIKE THIS: NOT LIKE THIS:

1. **How many pieces of fresh fruit do you usually eat per day?** *(Count 1/2 cup of diced fruit, berries or grapes as one piece.)*
   - I don't eat fruit
   - less than 1 piece of fruit per day
   - 1 piece of fruit per day
   - 2 pieces of fruit per day
   - 3 pieces of fruit per day
   - 4 or more pieces of fruit per day

2. **How many different vegetables do you usually eat per day?** *(Count all types, fresh, frozen or tinned.)*
   - less than 1 vegetable per day
   - 1 vegetable per day
   - 2 vegetables per day
   - 3 vegetables per day
   - 4 vegetables per day
   - 5 vegetables per day
   - 6 or more vegetables per day

3. **What type of milk do you usually use?**
   - none
   - full cream milk
   - reduced fat milk
   - skim milk
   - soya milk

4. **How much milk do you usually use per day?** *(Include flavoured milk and milk added to tea, coffee, cereal etc.)*
   - none
   - less than 250 ml *(1 large cup or mug)*
   - between 250 and 500 ml *(1-2 cups)*
   - between 500 and 750 ml *(2-3 cups)*
   - 750 ml *(3 cups)* or more

5. **What type of bread do you usually eat?**
   - I don't eat bread
   - high fibre white bread
   - white bread
   - wholemeal bread
   - rye bread
   - multi-grain bread

6. **How many slices of bread do you usually eat per day?** *(Include all types, fresh or toasted and count one bread roll as 2 slices.)*
   - less than 1 slice per day
   - 1 slice per day
   - 2 slices per day
   - 3 slices per day
   - 4 slices per day
   - 5-7 slices per day
   - 8 or more slices per day

7. **Which spread do you usually put on bread?**
   - I don't usually use any fat spread
   - margarine of any kind
   - polyunsaturated margarine
   - monounsaturated margarine
   - butter and margarine blends
   - butter

8. **On average, how many teaspoons of sugar do you usually use per day?** *(Include sugar taken with tea and coffee and on breakfast cereal etc.)*
   - none
   - 1 to 4 teaspoons per day
   - 5 to 8 teaspoons per day
   - 9 to 12 teaspoons per day
   - more than 12 teaspoons per day

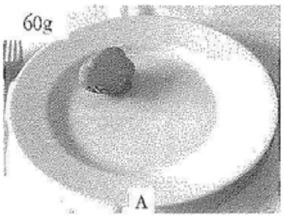
9. **On average, how many eggs do you usually eat per week?**
   - I don't eat eggs
   - less than 1 egg per week
   - 1 to 2 eggs per week
   - 3 to 5 eggs per week
   - 6 or more eggs per week

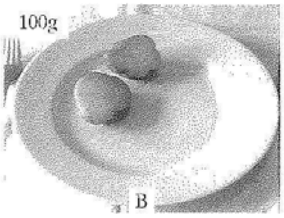
10. **What types of cheese do you usually eat?**
    - I don't eat cheese
    - hard cheeses, e.g. parmesan, romano
    - firm cheeses, e.g. cheddar, edam
    - soft cheeses, e.g. camembert, brie
    - ricotta or cottage cheese
    - cream cheese
    - low fat cheese

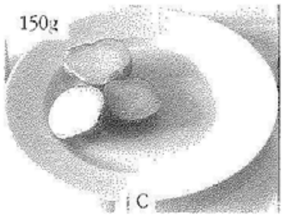
For each food shown on this page, indicate ***how much on average you would usually have eaten at main meals during the past 12 months.*** *When answering each question, think of the* ***amount*** *of that food you usually ate, even though you may rarely have eaten the food on its own.*

If you usually ate more than one helping, fill in the oval for the serving size closest to the ***total amount*** *you ate.*

11. When you ate potato, did you usually eat: ○ I never ate potato

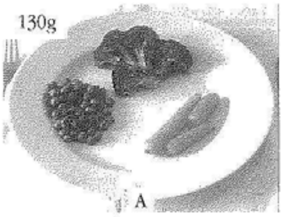


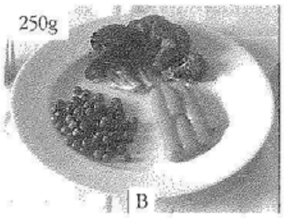


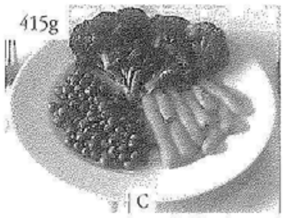


○	○	○	○	○	○	○
Less than A	A	Between A & B	B	Between B & C	C	More than C

12. When you ate vegetables, did you usually eat: ○ I never ate vegetables

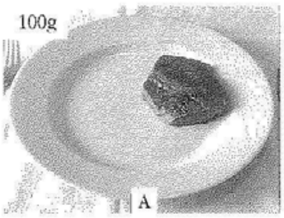


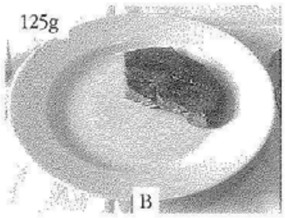


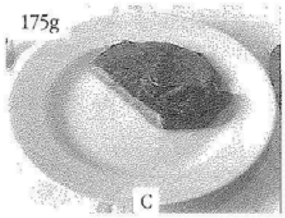


○	○	○	○	○	○	○
Less than A	A	Between A & B	B	Between B & C	C	More than C

13. When you ate steak, did you usually eat: ○ I never ate steak

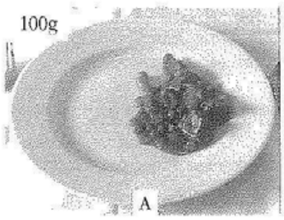


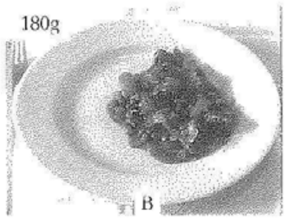


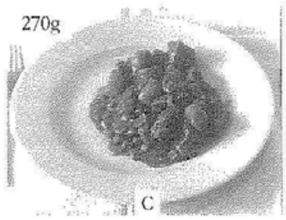


○	○	○	○	○	○	○
Less than A	A	Between A & B	B	Between B & C	C	More than C

14. When you ate meat *or* vegetable casserole, did you usually eat: ○ I never ate casserole







○	○	○	○	○	○	○
Less than A	A	Between A & B	B	Between B & C	C	More than C

2

5. **Over the last 12 months, on average, *how often* did you eat the following foods?** *Please completely fill one oval in every line.* Please MARK LIKE THIS: NOT LIKE THIS:

Times You Have Eaten

	NEVER	less than once (per month)	1 to 3 times (per month)	1 time (per week)	2 times (per week)	3 to 4 times (per week)	5 to 6 times (per week)	1 time (per day)	2 times (per day)	3 or more times (per day)
CEREAL FOODS, SWEETS & SNACKS										
All Bran™										
Sultana Bran™, FibrePlus™, Branflakes™										
Weet Bix™, Vita Brits™, Weeties™										
Cornflakes, Nutrigrain™, Special K™										
Porridge										
Muesli										
Rice										
Pasta or noodles (include lasagne)										
Crackers, crispbreads, dry biscuits										
Sweet biscuits										
Cakes, sweet pies, tarts and other sweet pastries										
Meat pies, pasties, quiche and other savoury pastries										
Pizza										
Hamburger with a bun										
Chocolate										
Flavoured milk drink (cocoa, Milo™ etc.)										
Nuts										
Peanut butter or peanut paste										
Corn chips, potato crisps, Twisties™ etc.										
Jam, marmalade, honey or syrups										
Vegemite™, Marmite™ or Promite™										
DAIRY PRODUCTS, MEAT & FISH										
Cheese										
Ice-cream										
Yoghurt										
Beef										
Veal										
Chicken										
Lamb										
Pork										
Bacon										
Ham										
Corned beef, luncheon meats or salami										
Sausages or frankfurters										
Fish, steamed, grilled or baked										
Fish, fried (include take-away)										
Fish, tinned (salmon, tuna, sardines etc.)										
FRUIT										
Tinned or frozen fruit (any kind)										
Fruit juice										
Oranges or other citrus fruit										
Apples										
Pears										
Bananas										
Watermelon, rockmelon (cantaloupe), honeydew etc.										
Pineapple										
Strawberries										
Apricots										
Peaches or nectarines										
Mango or paw paw										
Avocado										

3

Times You Have Eaten
CONTINUED

VEGETABLES (INCLUDING FRESH, FROZEN AND TINNED)	NEVER	less than once per month	1 to 3 times per month	1 time per week	2 times per week	3 to 4 times per week	5 to 6 times per week	1 time per day	2 times per day	3 or more times per day
Potatoes roasted or fried (include hot chips)										
Potatoes cooked without fat										
Tomato sauce, tomato paste or dried tomatoes										
Fresh or tinned tomatoes										
Peppers (capsicum)										
Lettuce, endive, or other salad greens										
Cucumber										
Celery										
Beetroot										
Carrots										
Cabbage or Brussels sprouts										
Cauliflower										
Broccoli										
Silverbeet or spinach										
Peas										
Green beans										
Bean sprouts or alfalfa sprouts										
Baked beans										
Soy beans, soy bean curd or tofu										
Other beans (include chick peas, lentils etc.)										
Pumpkin										
Onion or leeks										
Garlic (not garlic tablets)										
Mushrooms										
Zucchini										

16. **Over the last 12 months, how often did you drink beer, wine and/or spirits?**

Times That You Drank

	NEVER	less than once a month	1-3 days per month	1 day per week	2 days per week	3 days per week	4 days per week	5 days per week	6 days per week	every day
Beer (low alcohol)										
Beer (full strength)										
Red wine										
White wine (include sparkling wines)										
Fortified wines, port, sherry, etc.										
Spirits, liqueurs, etc.										

When answering the next two questions, please convert the amounts you drink into glasses using the examples given below. For spirits, liqueurs, and mixed drinks containing spirits, please count each nip (30 ml) as one glass.

1 can or stubby of beer = 2 glasses
1 large bottle beer (750 ml) = 4 glasses
1 bottle wine (750 ml) = 6 glasses
1 bottle of port or sherry (750 ml) = 12 glasses

17. **Over the last 12 months, on days when you were drinking, how many glasses of beer, wine and/or spirits altogether did you *usually* drink?**

	1	2	3	4	5	6	7	8	9	10 or more
TOTAL NUMBER OF GLASSES PER DAY										

18. **Over the last 12 months, what was the *maximum* number of glasses of beer, wine and/or spirits that you drank in 24 hours?**

	1-2	3-4	5-6	7-8	9-10	11-12	13-14	15-16	17-18	19 or more
MAXIMUM NUMBER OF GLASSES PER 24 HOURS										

Thank You for completing this questionnaire

4

Appendix B: Calcium Rich Foods

An average serve of a dairy food (or calcium rich alternative) should provide around 300 mg of calcium. Reduced fat varieties should be chosen where possible.

Some dairy and soy foods with limited calcium content have been listed.

Average Serving Sizes of Calcium-Rich Foods

Dairy Foods	Average serve size	Calcium content
Milk, whole	1 cup	294mg
Milk, reduced fat	1 cup	353mg
Evaporated milk	0.5 cup	354mg
Yoghurt, natural	1 tub (200g)	342mg
Yoghurt, reduced fat	1 tub (200g)	331mg
Cheese, cheddar	2 slices (40g)	310mg
Cheese, cheddar, reduced fat	2 slices (42g)	338mg
Cheese, ricotta	0.5 cup	293mg
Ice-cream, regular	2 cup	333mg
Ice-cream, reduced fat	1.5 cup	309mg
Custard, boiled	1 cup	296mg

Calcium-rich alternatives	Average serve size	Calcium content
Soy beverage, fortified	1 cup	281mg
Almonds	1 cup (132g)	310mg
Sardines	5 sardines (75g)	285mg
Pink Salmon	0.5 can (105g)	326mg
Breakfast cereal, fortified	1.5 cups (45g)	300mg
Tofu	100g	330mg

Dairy and Soy Foods with Limited Calcium Content

Calcium-rich alternatives	Average serve size	Calcium content
Cheese, cottage	0.5 cup	84mg
Cream, pure	0.5 cup	76mg
Soy beverage, not fortified	1 cup	31mg

Source: Data generated using Foodworks Professional Edition, Version 3.02.581, Xyris Software (Australia) Pty Ltd., Highgate Hill, Australia. Foodworks uses food composition data from the Nutrient Data Table for Use in Australia (Nuttab) 1995, Australian Government Publishing Service, Canberra, Australia.

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A Survey of Australian Defence Force (ADF) Trainees

Julia Carins

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19. ABSTRACT

Poor bone health is becoming increasingly common, and therefore is of concern for the ADF. Personnel at risk include those with habitually low dietary calcium intakes, or other dietary issues related to bone health. Dietary intakes of female cadets in training and male recruits upon entry to training were surveyed to determine whether individuals were at increased risk of poorer bone health. Approximately one third of respondents reported calcium intakes below the recommended levels, due to under-consumption of dairy foods. Female respondents were generally worse than their male counterparts. The majority of respondents reported at least two or more dietary risk factors that could negatively affect bone health.